United Kingdom of Great Britain and Northern Ireland

EDICT OF GOVERNMENT

In order to promote public education and public safety, equal justice for all, a better informed citizenry, the rule of law, world trade and world peace, this legal document is hereby made available on a noncommercial basis, as it is the right of all humans to know and speak the laws that govern them.

BS NA EN 1991-4 (2006) (English): UK National Annex to Eurocode 1. Actions on structures. Silos and tanks

Nulli vendemus, nulli negabimus aut differemus Rectum aut Justiciam.

We will sell to no man, we will not deny or defer to any man either Justice or Right.

MAGNA CARTA (1297)

BLANK PAGE

NA to BS EN 1991-4:2006

BSI Standards Publication

UK National Annex to Eurocode 1: Actions on structures –

Part 4: Silos and tanks

raising standards worldwide™

Publishing and copyright information

ISBN 978 0 580 67720 5

ICS 91.010.30

The following BSI references relate to the work on this standard:
Committee reference B/525/1
Draft for comment 09/30128355 DC

Publication history

First published November 2009

Amendments issued since publication

Date	Text affected

Summary of pages

This document comprises a front cover, an inside front cover, pages 1 to 10, an inside back cover and a back cover.

National Annex (informative) to BS EN 1991-4:2006, Eurocode 1: Actions on structures – Part 4: Silos and tanks

Introduction

This National Annex has been prepared by BSI Subcommittee B/525/1, *Actions (loadings) and basis of design*. In the UK it is to be used in conjunction with BS EN 1991-4:2006.

NOTE The UK committee has submitted amendments to BS EN 1991-4:2006, Expression 6.8 and Expression C.16.

NA.1 Scope

This National Annex gives:

a) the UK decisions for the Nationally Determined Parameters described in the following subclauses of BS EN 1991-4:2006:
   - **2.5**(5)
   - **3.6**(2)
   - **5.2.4.3.1**(3)
   - **5.4.1**(3)
   - **5.4.1**(4)
   - **A.4**(3)
   - **B.2.14**(1)

b) the UK decisions on the status of BS EN 1991-4:2006 informative annexes; and

c) references to non-contradictory complementary information.

NA.2 Nationally Determined Parameters

NA.2.1 General

UK decisions for the Nationally Determined Parameters described in BS EN 1991-4:2006 are given in **NA.2.2** to **NA.2.8**.

NA.2.2 Action assessment classes for a silo [BS EN 1991-4:2006, 2.5(5)]

UK decisions for action assessment classes for a silo are shown in Table NA.1.

Table NA.1 **Recommended classification of silos for action assessments**

Action Assessment Class	Description
Action Assessment Class 3	Silos with capacity in excess of 5 000 tonnes Silos with capacity in excess of 200 tonnes in which any of the following design situations occur: a) eccentric discharge with $e_o/d_c > 0,25$ (see BS EN 1991-4:2006, Figure 1.1b) b) squat silos with top surface eccentricity with $e_t/d_c > 0,25$ c) all silos not supported fully all around the circumference d) silos used for homogenising and blending, and silos containing internal structures
Action Assessment Class 2	All silos covered by this standard and not placed in another class
Action Assessment Class 1	Silos with capacity below 100 tonnes

NOTE The values are to be defined for the individual project, using the values in this table as a minimum.

NA.2.3 Guidance on the pressure exerted on structures near the silo as a result of an explosion within it [BS EN 1991-4:2006, 3.6(2)]

The appropriate pressures acting on adjacent structures as a result of an explosion within a silo should be determined by any rational method, and defined for the individual project as appropriate in consultation with the client.

NA.2.4 Values of k_1, k_2 and k_3 [BS EN 1991-4:2006, 5.2.4.3.1(3)]

The following values should be used:

- $k_1 = 0,35$;
- $k_2 = 0,50$;
- $k_3 = 0,65$.

Further large values of k should be explored for more slender silos.

NA.2.5 Method to be used for determining the horizontal pressure p_h [BS EN 1991-4:2006, 5.4.1(3)]

The recommended expression should be used.

NA.2.6 Method to be used for determining the resulting vertical forces n_{zSk} [BS EN 1991-4:2006, 5.4.1(4)]

The recommended expression should be used.

NA.2.7 Values of combination factor ψ [BS EN 1991-4:2006, A.4(3)]

Table NA.A.1, Table NA.A.2, Table NA.A.3, Table NA.A.4 and Table NA.A.5 of Annex NA.A of this National Annex should be used.

NA.2.8 Loads resulting from accidental actions on tanks [BS EN 1991-4:2006, B.2.14(1)]

The loads should be agreed for an individual project with the client.

NA.3 Decisions on the status of BS EN 1991-4:2006 informative annexes

NA.3.1 Basis of design – supplementary paragraphs to EN 1990 for silos and tanks [BS EN 1991-4:2006, Annex A]

BS EN 1991-4:2006, Annex A, should not be used. Annex NA.A of this National Annex should be used instead.

NA.3.2 Actions, partial factors and combinations of actions on tanks [BS EN 1991-4:2006, Annex B]

BS EN 1991-4:2006, Annex B, should not be used. Annex NA.A of this National Annex should be used instead.

NA.3.3 Flow pattern determination [BS EN 1991-4:2006, Annex F]

BS EN 1991-4:2006, Annex F, may be used.

NA.3.4 Actions due to dust explosions [BS EN 1991-4:2006, Annex H]

BS EN 1991-4:2006, Annex H, may be used.

NA.4 References to non-contradictory complementary information

The following is a list of references that contain non-contradictory complementary information for use with BS EN 1991-4:2006.

BS 5975, *Code of practice for temporary works procedures and the permissible stress design of falsework*

BS 6187, *Code of practice for demolition*

BRITISH CONSTRUCTIONAL STEELWORK ASSOCIATION. BCSA Publication No 39/05, *Guide to steel erection in windy conditions*. London: BCSA, 2005.

Annex A (informative) Basis of design – supplementary paragraphs to BS EN 1990 for silos and tanks

NA.A.1 General

In principle, the general format given in BS EN 1990 for design procedures is applicable. However, silos and tanks are different from many other structures because they can be subjected to the full loads from particulate solids or liquids for most of their life.

This annex provides supplementary guidance applicable to silos or tanks regarding partial factors on actions (termed γ_F factors in BS EN 1991-4) and on combinations on silos and tanks with other actions, and the relevant ψ factors (see Table NA.A.1, Table NA.A.2, Table NA.A.3, Table NA.A.4 and Table NA.A.5).

Thermal actions include climatic effects and the effects of hot solids or liquids. Design situations that should be considered include:

- hot solid or liquid filled into a partly filled silo or tank. The effects of heated air above the stored material should be considered;
- resistance of the stored solid to silo wall contraction during cooling.

Determination of the effect of differential settlements of batteries of silo or tank cells should be based on the worst combination of full and empty cells.

NA.A.2 Ultimate limit state

NA.A.2.1 Partial factors γ

The values given in BS EN 1990:2002+A1, **A.1**, may be used for the design of silos and tanks.

In a tank, the value of the partial safety factor γ_Q may be taken for the liquid induced loads as follows:

- $\gamma_Q = 1{,}20$ during operation, applied to the stored liquid at the maximum design liquid level;
- $\gamma_Q = 1{,}00$ during test, applied to the test medium at the maximum test liquid level;
- $\gamma_Q = 1{,}00$ for accidental design situations.

NA.A.2.2 Combination factors ψ

For the combination factors ψ for silo loads, tank loads and combination factors with other actions, see **NA.A.4**.

NA.A.3 Actions for combination

The following actions should be considered in the ultimate limit state design as relevant:

- in a silo, filling and storage of particulate solids (referred to as filling loads in BS EN 1991-4);
- in a silo, discharge of particulate solids (referred to as discharge loads in BS EN 1991-4);

- in a tank, operational loads and test loads;
- imposed loads (see BS EN 1991-1-1);
- snow loads (see BS EN 1991-1-3);
- wind action when the silo or tank is either full or empty (see BS EN 1991-1-4);
- thermal loads (see BS EN 1991-1-5);
- imposed deformations: foundation settlement (see BS EN 1997-1);
- seismic loads (see BS EN 1998-1);
- dust explosion loads in silos (see BS EN 1991-1-7).

NA.A.4 Design situations and action combinations for all tanks and for silos in Action Assessment Classes 2 and 3

NA.A.4.1 The design situations given in Table NA.A.1 should be considered. BS EN 1991-4:2006, Section 3, should also be referred to for additional design situations specific to certain forms of construction or operation. The relevant design values of actions should be based on the NA to BS EN 1990:2002+A1, Table NA.A1.2 (B). With respect to foundation settlement, the relevant design values of actions should be based on the NA to BS EN 1990:2002+A1, Table NA.A1.2 (C).

NA.A.4.2 The actions should be combined in accordance with BS EN 1990, using the appropriate combination factor ψ as given in Table NA.A.5 to account for the reduced probability of simultaneous occurrence.

NA.A.4.3 For accidental or seismic design situations, the relevant design values of actions should be obtained from the NA to BS EN 1990:2002+A1, Table NA.A1.3.

NA.A.4.4 For accidental or seismic design situations in silos, the accompanying solids loading may be obtained using the single value of the mean wall friction coefficient μ_m, the mean lateral pressure ratio K_m and the mean hopper pressure ratio F_m for the stored particulate solid, provided the appropriate procedures in BS EN 1991-4:2006, **5.2**, **5.3** and **6.1**, are adopted.

NA.A.4.5 The seismic design situation should be taken into account as agreed for an individual project with the client and the relevant authority (see also BS EN 1998).

NA.A.4.6 Loss of static equilibrium should be considered in accordance with BS EN 1990:2002+A1, **6.4.2**, using Expression 6.10 applied to design situations WE (Table NA.A.1) and SF (Table NA.A.4). The relevant design values of actions should be obtained from the NA to BS EN 1990:2002+A1, Table NA.A1.2 (A).

NA.A.4.7 For the serviceability limit states to be considered in applying BS EN 1990:2002+A1, Expression 6.14b, Expression 6.15b and Expression 6.16b, the design situations in Table NA.A.1 should be used together with appropriate serviceability criteria. These criteria should be defined in relation to the serviceability requirements in accordance with BS EN 1990:2002+A1, **3.4**, and BS EN 1992 to BS EN 1999.

Deformations should be calculated in accordance with BS EN 1991 to BS EN 1999 as relevant, by using the appropriate combinations of actions according to BS EN 1990:2002+A1, Expression 6.14b, Expression 6.15b or Expression 6.16b (see Table NA.A.5), taking into account the serviceability requirements and the distinction between reversible and irreversible limit states.

NA.A.4.8 Serviceability requirements and criteria should be agreed for an individual project with the client.

Table NA.A.1 **Design situations for ultimate limit states to be considered in applying BS EN 1990:2002+A1, Expression 6.10**

Short title	Permanent actions	Design situation/Leading variable action 1	Accompanying action 2	Accompanying action 3
D	Self weight[A)]	Solids discharge from a silo	Foundation settlement	Snow or wind or thermal and imposed loads or deformation
LO	Self weight[A)]	Tank full of liquid to be stored to maximum design liquid level	Foundation settlement	Snow or wind or thermal and imposed loads or deformation
LT	Self weight[A)]	Tank full of test medium to maximum test liquid level		
I	Self weight[A)]	Imposed loads or deformation	Silo with solids filling or full tank	Snow or wind or thermal
S	Self weight[A)]	Snow	Silo with solids filling or full tank	
WF	Self weight[A)]	Wind and full silo or tank	Silo with solids filling or full tank	
WE	Self weight[A)]	Wind and empty silo or tank	Silo or tank empty	
T	Self weight[A)]	Thermal	Silo with solids filling or full tank	
F	Self weight[A)]	Foundation settlement	Solids discharge from a silo or full tank	Snow or wind or thermal

A) Self weight refers to the weight of the structure alone.

Table NA.A.2 **Design situations for ultimate limit states to be considered in applying BS EN 1990:2002+A1, Expression 6.10a and Expression 6.10b**

BS EN 1990:2002+A1, Expression 6.10a and Expression 6.10b, should not be used in the UK for the design of silos and tanks.

Table NA.A.3 **Design situations for accidental limit states to be considered in applying BS EN 1990:2002+A1, Expression 6.11b**

Short title	Design situation	Permanent actions	Leading accidental action	Accompanying variable action 1 (main)	Accompanying variable action 2	Accompanying variable action 3, 4, etc.
E	Explosion	Self weight [A)]	Blast pressure	Silo with solids filling or full tank	Imposed deformation	Imposed loads
V	Vehicle impact	Self weight [A)]	Vehicle impact	Silo with solids filling or full tank	Imposed deformation	Imposed loads

[A)] Self weight refers to the weight of the structure alone.

Table NA.A.4 **Design situations for seismic limit states to be considered in applying BS EN 1990:2002+A1, Expression 6.12b**

Short title	Design situation	Permanent actions	Leading seismic action	Accompanying variable action 1 (main)	Accompanying variable action 2	Accompanying variable action 3, 4, etc.
SF	Seismic action and full silo or tank	Self weight [A)]	Seismic action (earthquake)	Silo with solids filling or full tank	Imposed deformation	Imposed loads
SE	Seismic action and empty silo or tank	Self weight [A)]	Seismic action (earthquake)	Silo or tank empty	Imposed deformation	Imposed loads

[A)] Self weight refers to the weight of the structure alone.

Table NA.A.5 **Design situations for serviceability limit states to be considered in applying BS EN 1990:2002+A1, Expressions 6.10, 6.11b, 6.12b, 6.14b, 6.15b and 6.16b**

Actions	ψ_0	ψ_1	ψ_2
Foundation settlement	1,0	1,0	1,0
Imposed loads or deformation	0,7	0,5	0,3
Snow loads	0,5	0,2	0,0
Wind actions	0,5	0,2	0,0
Thermal actions	0,6	0,5	0,0
Solids filling	1,0	0,9	0,3
Liquid loads	1,0	0,9	0,3
Solids discharge	1,0	0,3	0,3

NA.A.5 Action combinations for silos in Action Assessment Class 1

For silos in Action Assessment Class 1, the following simplified load combination expression may be used:

Total load = (1,35 × self weight) + (1,5 × variable load),

where the variable load is any of the following:

- discharge;
- wind when empty;
- filling with wind;
- snow (for the roof).

Bibliography

Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 5975, *Code of practice for temporary works procedures and the permissible stress design of falsework*

BS 6187, *Code of practice for demolition*

BS EN 1990:2002+A1:2005, *Eurocode – Basis of structural design* (including the National Annex)

BS EN 1991 (all parts), *Eurocode 1 – Actions on structures*

BS EN 1991-1-1, *Eurocode 1 – Actions on structures – Part 1-1: General actions – Densities, self-weight, imposed loads for buildings*

BS EN 1991-1-3, *Eurocode 1 – Actions on structures – Part 1-3: General actions – Snow loads*

BS EN 1991-1-4, *Eurocode 1 – Actions on structures – Part 1-4: General actions – Wind actions*

BS EN 1991-1-5, *Eurocode 1 – Actions on structures – Part 1-5: General actions – Thermal actions*

BS EN 1991-1-7, *Eurocode 1 – Actions on structures – Part 1-7: General actions – Accidental actions*

BS EN 1992 (all parts), *Eurocode 2 – Design of concrete structures*

BS EN 1993 (all parts), *Eurocode 3 – Design of steel structures*

BS EN 1994 (all parts), *Eurocode 4 – Design of composite steel and concrete structures*

BS EN 1995 (all parts), *Eurocode 5 – Design of timber structures*

BS EN 1996 (all parts), *Eurocode 6 – Design of masonry structures*

BS EN 1997 (all parts), *Eurocode 7 – Geotechnical design*

BS EN 1997-1, *Eurocode 7 – Geotechnical design – Part 1: General rules*

BS EN 1998 (all parts), *Eurocode 8 – Design of structures for earthquake resistance*

BS EN 1998-1, *Eurocode 8 – Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings*

BS EN 1999 (all parts), *Eurocode 9 – Design of aluminium structures*

Other publications

BRITISH CONSTRUCTIONAL STEELWORK ASSOCIATION. BCSA Publication No 39/05, *Guide to steel erection in windy conditions*. London: BCSA, 2005.

Further reading

Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS EN 1993-1-6, *Eurocode 3 – Design of steel structures – Part 1-6: Strength and stability of shell structures*

BS EN 1993-4-1, *Eurocode 3 – Design of steel structures – Part 4-1: Silos*

BS EN 1993-4-2, *Eurocode 3 – Design of steel structures – Part 4-2: Tanks*

BS EN 1998-4, *Eurocode 8 – Design of structures for earthquake resistance – Part 4: Silos, tanks and pipelines*

AS 3774-1996, *Loads on bulk solids containers* [1)]

DIN 1055-6, *Actions on structures – Part 6 – Design loads for buildings and loads in silo bins* [2)]

Other publications

[1] BRITISH MATERIALS HANDLING BOARD AND BRITISH STANDARDS INSTITUTION. *Silos: Draft Design Code for Silos, Bins, Bunkers and Hoppers*. London: BSI, 1987.

[2] ROTTER, J.M. *Guide for the Economic Design of Circular Metal Silos*. London: Spon Press, 2001.

[3] MARTENS, P. (ed). *Silo-Handbuch*. Berlin: Ernst und Sohn, 1988.

[4] HAMPE, E. *Silos: Band 1 Grundlagen, Band 2 Bauwerke*. Berlin: Verlag für Bauwesen GmbH, 1991.

[5] BROWN, C.J. AND NIELSEN, J. (eds). *Silos: Fundamentals of Theory, Behaviour and Design*. London: E & FN Spon, 1998.

[6] ROTTER, J.M. *Silo and hopper design for strength*, Chapter 3 in *Bulk Solids Handling – Equipment Selection and Operation*, Ed D. McGlinchey. Oxford: Blackwell, 2008. pp 99–134.

1) Available from www.standards.org.au.

2) Available from www.din.de.

British Standards Institution (BSI)

BSI is the independent national body responsible for preparing British Standards and other standards-related publications, information and services. It presents the UK view on standards in Europe and at the international level.

BSI is incorporated by Royal Charter. British Standards and other standardisation products are published by BSI Standards Limited.

Revisions

British Standards and PASs are periodically updated by amendment or revision. Users of British Standards and PASs should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using British Standards would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover. Similary for PASs, please notify BSI Customer Services.

Tel: +44 (0)20 8996 9001 Fax: +44 (0)20 8996 7001

BSI offers BSI Subscribing Members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of British Standards and PASs.

Tel: +44 (0)20 8996 7669 Fax: +44 (0)20 8996 7001
Email: plus@bsigroup.com

Buying standards

You may buy PDF and hard copy versions of standards directly using a credit card from the BSI Shop on the website **www.bsigroup.com/shop.** In addition all orders for BSI, international and foreign standards publications can be addressed to BSI Customer Services.

Tel: +44 (0)20 8996 9001 Fax: +44 (0)20 8996 7001
Email: orders@bsigroup.com

In response to orders for international standards, BSI will supply the British Standard implementation of the relevant international standard, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Knowledge Centre.

Tel: +44 (0)20 8996 7004 Fax: +44 (0)20 8996 7005 Email: knowledgecentre@bsigroup.com

BSI Subscribing Members are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration.

Tel: +44 (0)20 8996 7002 Fax: +44 (0)20 8996 7001 Email: membership@bsigroup.com

Information regarding online access to British Standards and PASs via British Standards Online can be found at **www.bsigroup.com/BSOL**

Further information about British Standards is available on the BSI website at **www.bsi-group.com/standards**

BSI

389 Chiswick High Road London W4 4AL UK

Tel +44 (0)20 8996 9001
Fax +44 (0)20 8996 7001
www.bsigroup.com/standards

raising standards worldwide™